



(12) **United States Patent**  
**Hotelling et al.**

(10) **Patent No.:** **US 9,075,491 B2**  
(45) **Date of Patent:** **\*Jul. 7, 2015**

(54) **DOUBLE-SIDED TOUCH-SENSITIVE PANEL WITH SHIELD AND DRIVE COMBINED LAYER**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(21) Appl. No.: **14/340,262**

(22) Filed: **Jul. 24, 2014**

(65) **Prior Publication Data**

US 2014/0333857 A1 Nov. 13, 2014

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**Related U.S. Application Data**

(63) Continuation of application No. 13/078,789, filed on Apr. 1, 2011, now Pat. No. 8,884,890, which is a continuation of application No. 11/650,182, filed on Jan. 3, 2007, now Pat. No. 7,920,129.

(51) **Int. Cl.**  
**G09G 5/00** (2006.01)  
**G06F 3/044** (2006.01)  
(Continued)

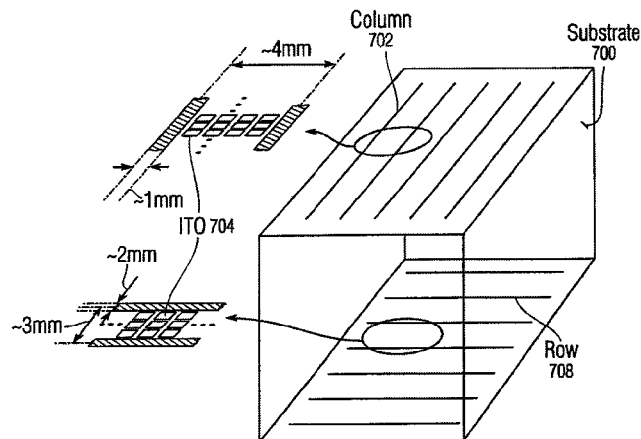
(52) **U.S. Cl.**  
CPC ..... **G06F 3/044** (2013.01); **G06F 3/0416** (2013.01); **G06F 2203/04107** (2013.01); **G06F 1/1692** (2013.01); **G06F 2203/04104** (2013.01)

(58) **Field of Classification Search**  
CPC G06F 3/044; G06F 3/042; G06F 2203/04112  
USPC ..... 345/173–174; 178/18.06  
See application file for complete search history.

(57) **ABSTRACT**

A multi-touch capacitive touch sensor panel can be created using a substrate with column and row traces formed on either side of the substrate. To shield the column (sense) traces from the effects of capacitive coupling from a modulated Vcom layer in an adjacent liquid crystal display (LCD) or any source of capacitive coupling, the row traces can be widened to shield the column traces, and the row traces can be placed closer to the LCD. In particular, the rows can be widened so that there is spacing of about 30 microns between adjacent row traces. In this manner, the row traces can serve the dual functions of driving the touch sensor panel, and also the function of shielding the more sensitive column (sense) traces from the effects of capacitive coupling.

**25 Claims, 7 Drawing Sheets**



- (51) **Int. Cl.**  
**G06F 3/041** (2006.01)  
**G06F 1/16** (2006.01)

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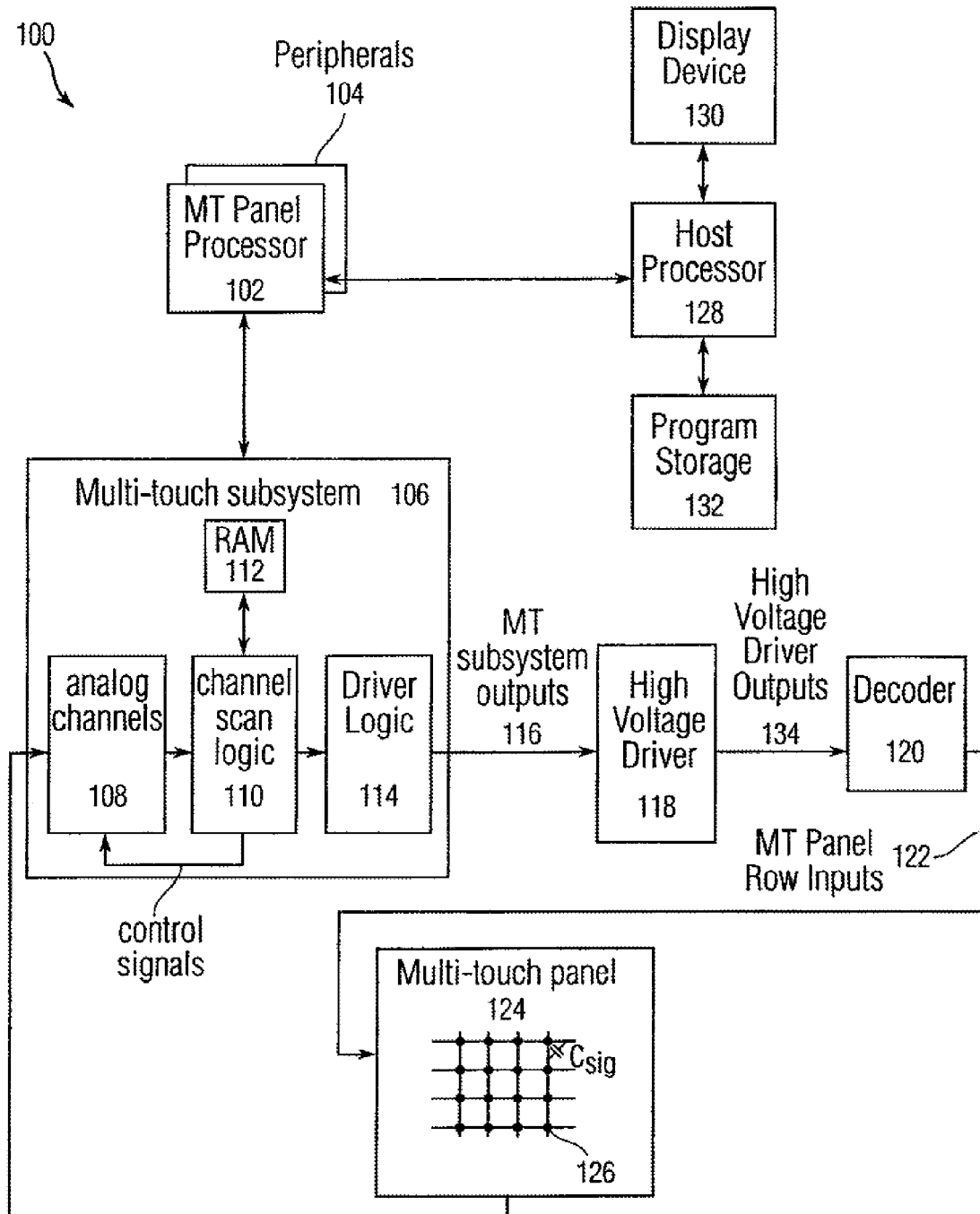


Fig. 1

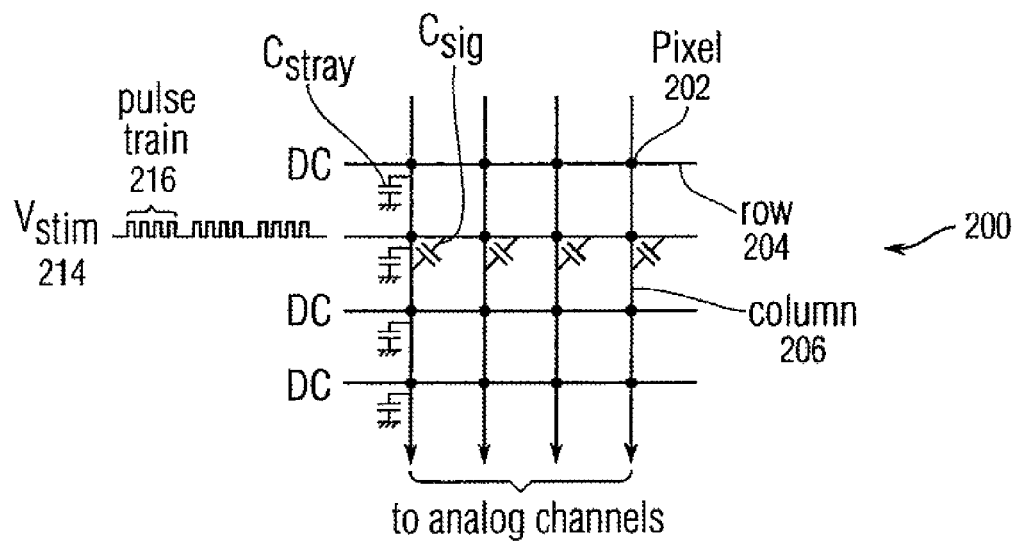


Fig. 2a

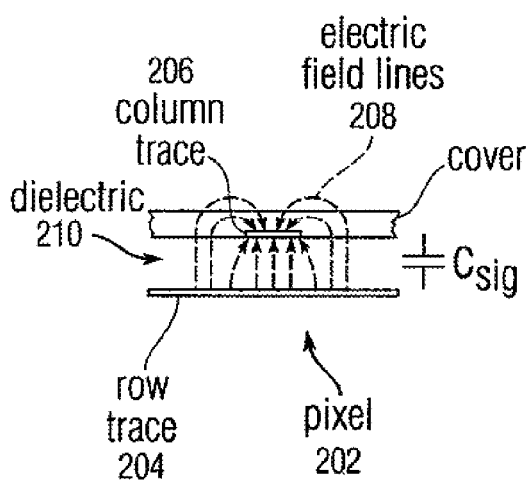


Fig. 2b

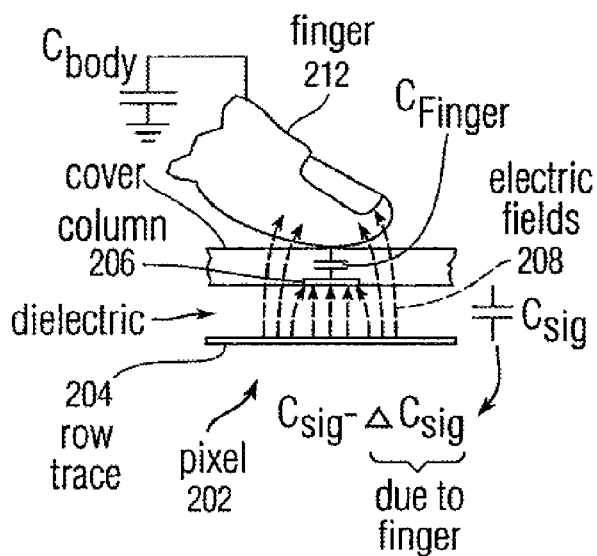


Fig. 2c

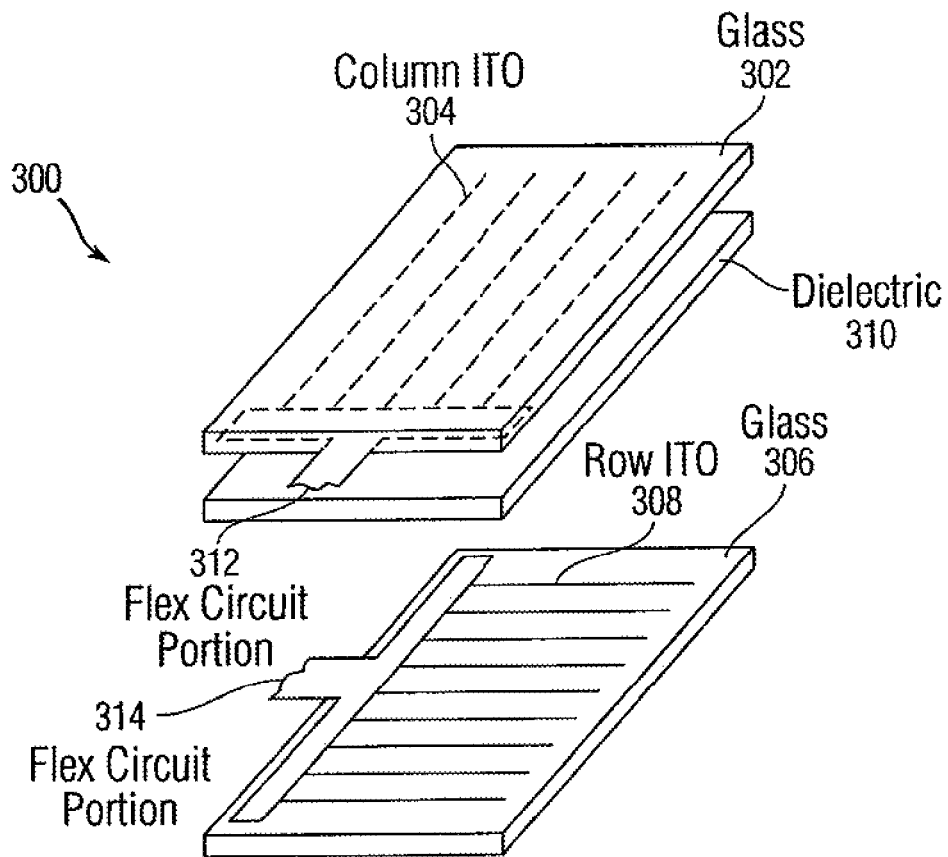


Fig. 3

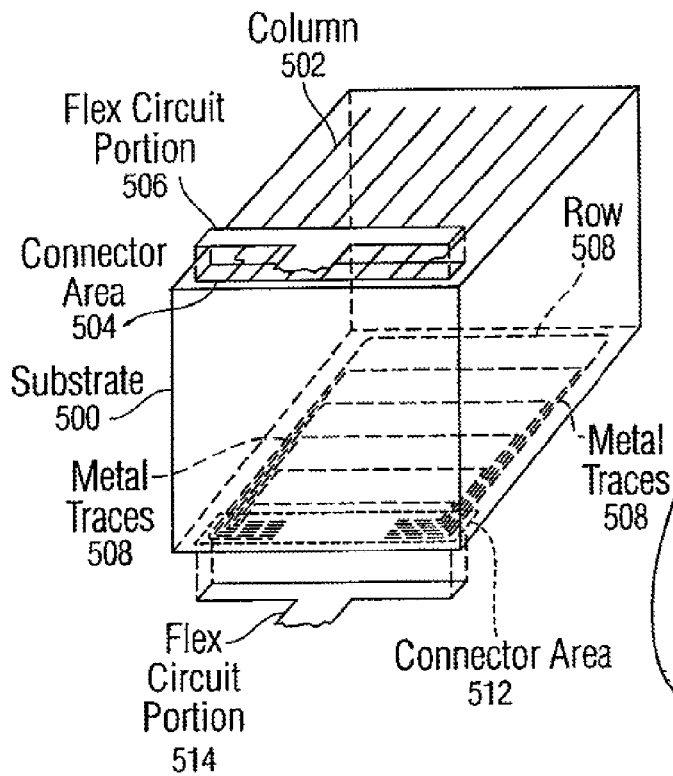
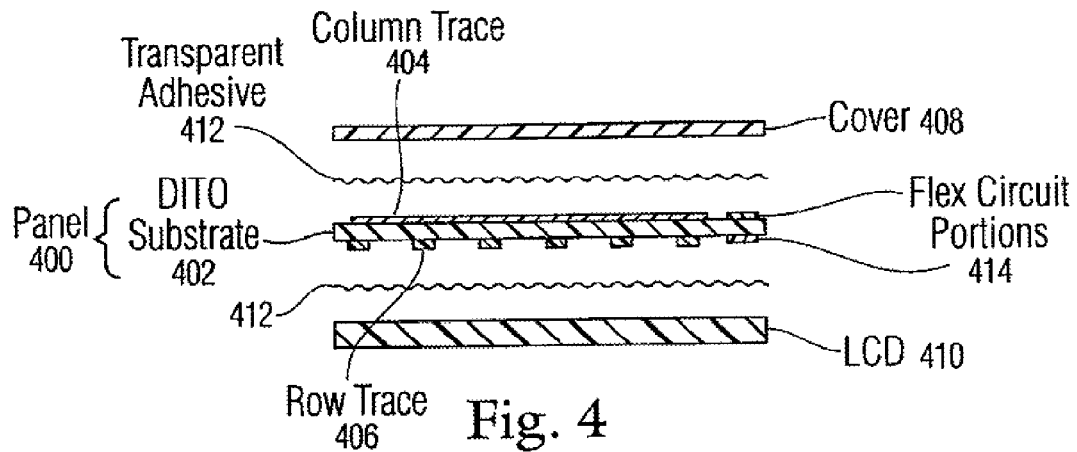


Fig. 5

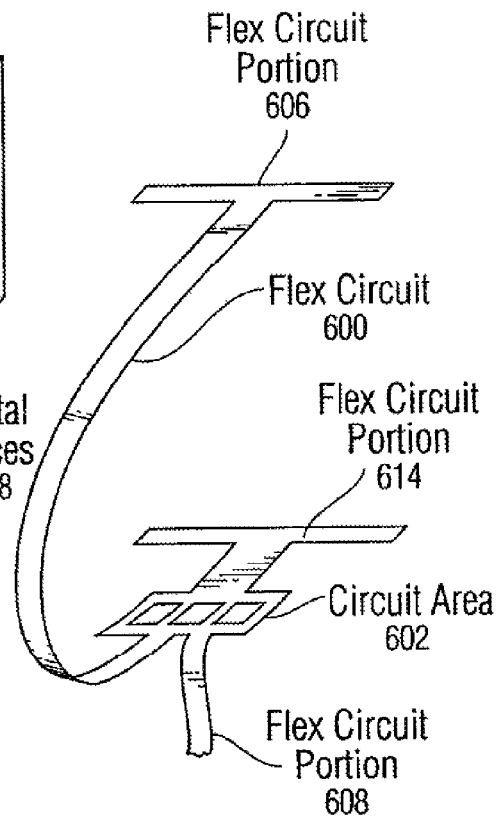


Fig. 6

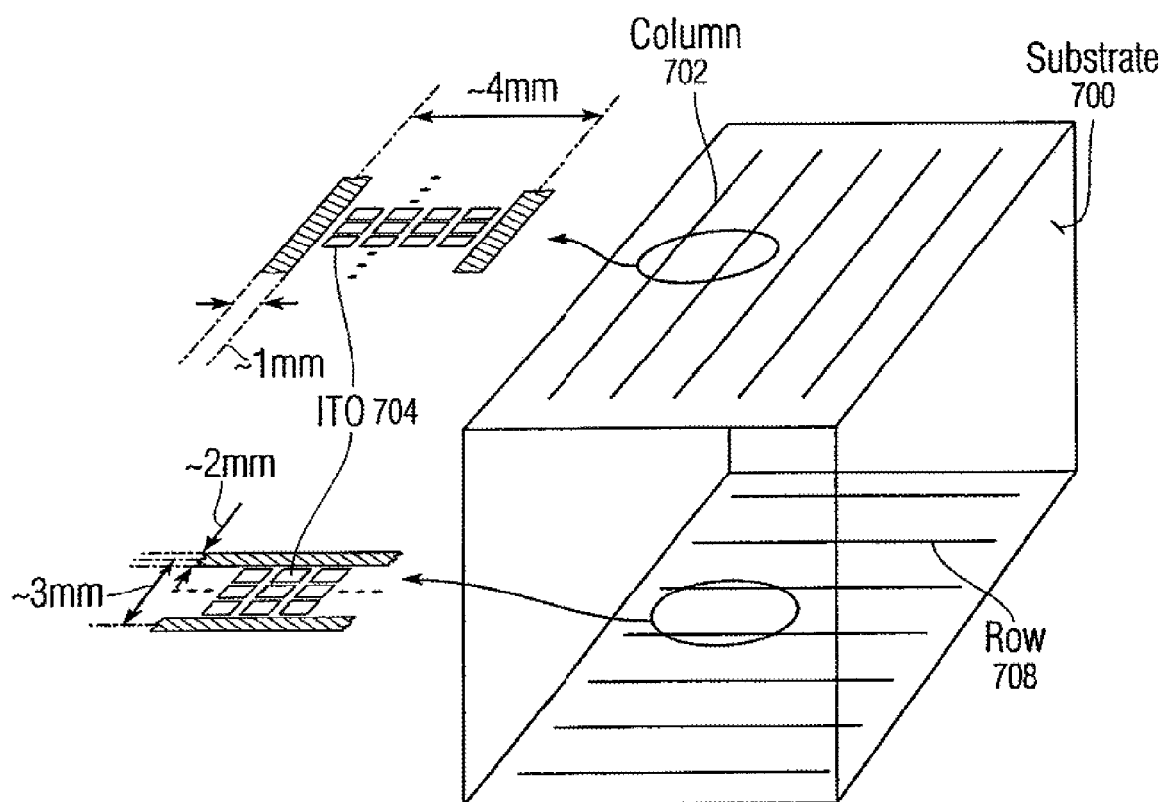
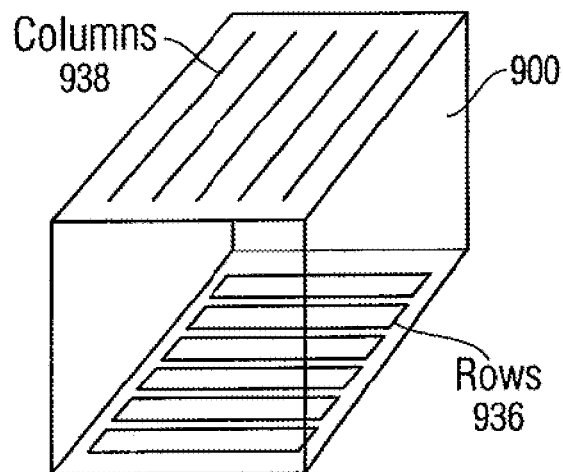
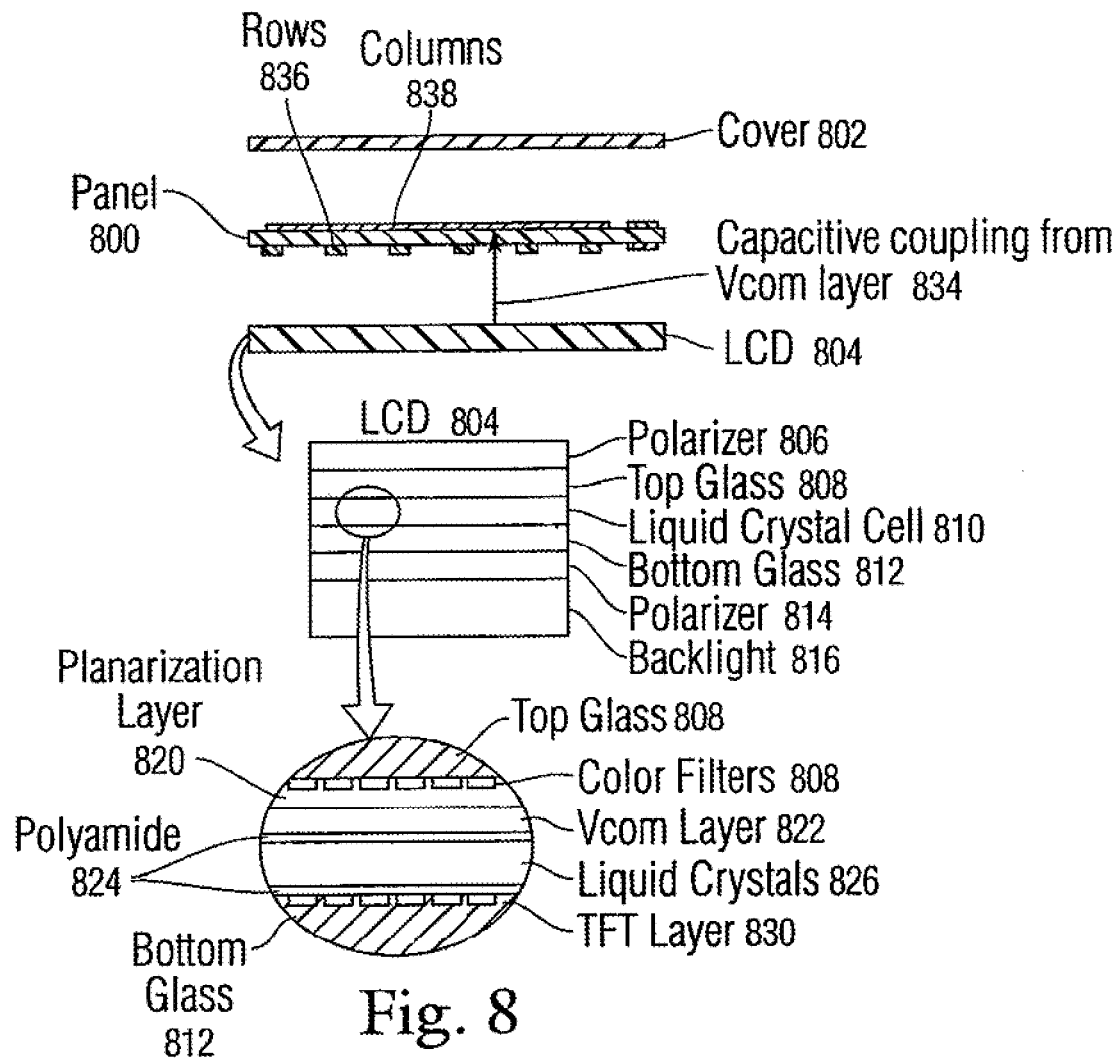


Fig. 7





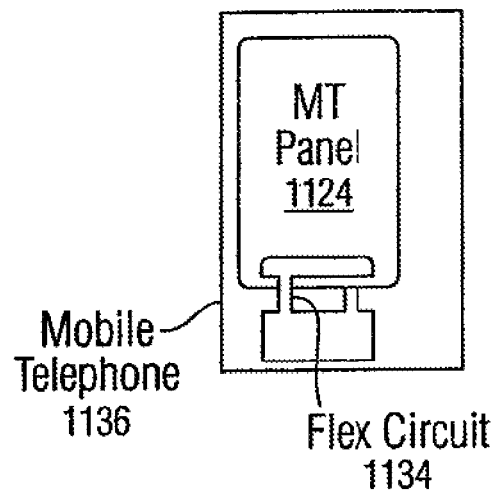


Fig. 10a

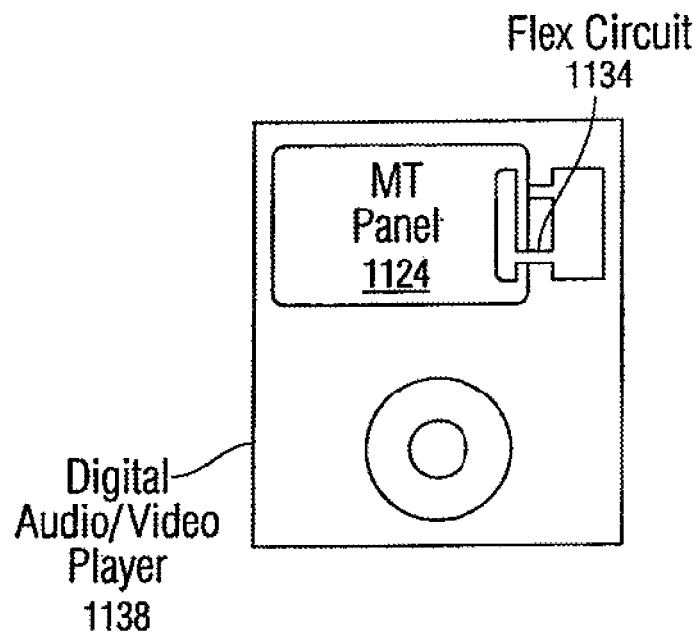


Fig. 10b

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## DOUBLE-SIDED TOUCH-SENSITIVE PANEL WITH SHIELD AND DRIVE COMBINED LAYER

### FIELD OF THE DISCLOSURE

This invention relates to touch sensor panels, and more particularly, to capacitive multi-touch sensor panels having rows and columns formed on either sides of the same substrate.

### BACKGROUND OF THE DISCLOSURE

Many types of input devices are presently available for performing operations in a computing system, such as buttons or keys, mice, trackballs, touch panels, joysticks, touch screens and the like. Touch screens, in particular, are becoming increasingly popular because of their ease and versatility of operation as well as their declining price. Touch screens can include a touch panel, which can be a clear panel with a touch-sensitive surface. The touch panel can be positioned in front of a display screen so that the touch-sensitive surface covers the viewable area of the display screen. Touch screens can allow a user to make selections and move a cursor by simply touching the display screen via a finger or stylus. In general, the touch screen can recognize the touch and position of the touch on the display screen, and the computing system can interpret the touch and thereafter perform an action based on the touch event.

Touch panels can include an array of touch sensors capable of detecting touch events (the touching of fingers or other objects upon a touch-sensitive surface). Future panels may be able to detect multiple touches (the touching of fingers or other objects upon a touch-sensitive surface at distinct locations at about the same time) and near touches (fingers or other objects within the near-field detection capabilities of their touch sensors), and identify and track their locations. Examples of multi-touch panels are described in Applicant's co-pending U.S. application Ser. No. 10/842,862 entitled "Multipoint Touchscreen," filed on May 6, 2004 and published as U.S. Published Application No. 2006/0097991 on May 11, 2006, the contents of which are incorporated by reference herein.

Capacitive touch sensor panels can be formed from rows and columns of traces on opposite sides of a dielectric. At the "intersections" of the traces, where the traces pass above and below each other (but do not make direct electrical contact with each other), the traces essentially form two electrodes. Conventional touch panels for use over display devices have typically utilized a top layer of glass upon which transparent column traces of indium tin oxide (ITO) or antimony tin oxide (ATO) have been etched, and a bottom layer of glass upon which row traces of ITO have been etched. However, the use of transparent traces is not required if the conductors are thin enough (on the order of 30 microns). In addition, if panel transparency is not required (e.g. the touch panel is not being used over a display device), the conductors can be made out of an opaque material such as copper. The top and bottom glass layers are separated by a clear polymer spacer that acts as a dielectric between the row and column traces. The traces on both the top and bottom glass layers can have a spacing of about 5 mm.

To scan a sensor panel, a stimulus can be applied to one row with all other rows held at DC voltage levels. When a row is stimulated, a modulated output signal can be capacitively coupled onto the columns of the sensor panel. The columns can be connected to analog channels (also referred to herein

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as event detection and demodulation circuits). For every row that is stimulated, each analog channel connected to a column generates an output value representative of an amount of change in the modulated output signal due to a touch or hover event occurring at the sensor located at the intersection of the stimulated row and the connected column. After analog channel output values are obtained for every column in the sensor panel, a new row is stimulated (with all other rows once again held at DC voltage levels), and additional analog channel output values are obtained. When all rows have been stimulated and analog channel output values have been obtained, the sensor panel is said to have been "scanned," and a complete "image" of touch or hover can be obtained over the entire sensor panel. This image of touch or hover can include an analog channel output value for every pixel (row and column) in the panel, each output value representative of the amount of touch or hover that was detected at that particular location.

Because the rows must be either stimulated with an AC signal or held at a DC voltage level, and because the columns must be connected to analog channels so that modulated output signals can be detected, demodulated and converted to output values, electrical connections must be formed with the rows and columns on either side of the dielectric of the sensor panel. Because the rows and columns are perpendicular to each other, the most straightforward way to connect to these rows and columns is to bond a flex circuit at one edge of the sensor panel (e.g. the shorter side of a rectangular panel) to provide connections to the columns, and bond another flex circuit on an adjacent edge of the sensor panel (e.g. the longer side of a rectangular panel) to provide connections to the rows. However, because these flex circuit connections areas are not on the same edge of the sensor panel and are not on directly opposing sides of the dielectric, the sensor panel must be made larger to accommodate these two non-overlapping connection areas.

Furthermore, when a transparent capacitive touch sensor panel is bonded to a liquid crystal display (LCD), a modulated Vcom layer in the LCD can couple onto the columns of the sensor panel, causing noise to appear on the columns.

### SUMMARY OF THE DISCLOSURE

A multi-touch sensor panel can be created using a substrate with column and row traces formed on either side of the substrate using a novel fabrication process. Flex circuits can be used to connect the column and row traces on either side of the sensor panel to its associated sensor panel circuitry. Traces made of copper or other highly conductive metals running along the edge of the substrate can be used to bring the row traces to the same edge of the substrate as the column traces so that the flex circuits can be bonded to the same edge of the substrate on directly opposing sides of the substrate, minimizing the area needed for connectivity and reducing the overall size of the sensor panel. A single flex circuit can be fabricated to connect to the rows and columns on directly opposing sides at the same edge of the substrate. Furthermore, the row traces can be widened to shield the column traces from a modulated Vcom layer.

Column and row ITO traces can be formed on both sides of a DITO substrate using several fabrication methods. In one embodiment, a substrate can be placed on the rollers of the fabrication machinery and a layer of ITO can be sputtered onto a first side of the DITO substrate and etched (e.g. using photolithography techniques) to form the column traces. A protective coating of photoresist (e.g. two layers of photoresist) can then be applied over the column traces, and the DITO

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substrate can be flipped over so that the rollers make contact only with the applied photoresist on the first side and not the formed column traces. Another layer of ITO can then be sputtered onto the now-exposed back side of the DITO substrate and etched to form row traces **508**.

If no metal traces are required, the photoresist on the first side can be stripped off to complete the process. However, if metal traces are required at the edges to connect to the row traces and bring them to a particular edge of the substrate, a protective coating of photoresist (e.g. two layers of photoresist) can be applied over the row traces, leaving the edges exposed. A metal layer can then be sputtered over the photoresist and exposed edges, and the metal layer can then be etched to form metal traces at the edges. Finally, all remaining layers of photoresist can be stripped off.

Flex circuit portions on a single flex circuit can be formed for connecting to the row and column traces, respectively, on either side of a DITO substrate, and to a host processor. The flex circuit can also include a circuit area upon which a multi-touch subsystem, multi-touch panel processor, high voltage driver and decoder circuitry, an EEPROM and some essential small components such as bypass capacitors can be mounted and connected to save space.

The rows of the DITO substrate can also be widened for shielding purposes and for providing a uniform appearance according to embodiments of this invention. To prevent the capacitive coupling of a modulated Vcom layer onto the columns of the substrate, the rows may be widened. The number of rows does not change, but they can be much wider, leaving only about 30 microns of space between them. Because these wider rows are not isolated but are instead either held at a DC voltage or stimulated with a stimulation voltage, these wider rows act as a shield, preventing a modulated Vcom layer from capacitively coupling onto the columns. In addition, because of the narrow spacing between them, the wide rows provide a uniform appearance. Thus, shielding, modulation and a uniform appearance can be obtained from a single layer of ITO.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an exemplary computing system operable with a capacitive multi-touch sensor panel according to one embodiment of this invention.

FIG. **2a** illustrates an exemplary capacitive multi-touch panel according to one embodiment of this invention.

FIG. **2b** is a side view of exemplary pixel in a steady-state (no-touch) condition according to one embodiment of this invention.

FIG. **2c** is a side view of exemplary pixel in a dynamic (touch) condition according to one embodiment of this invention.

FIG. **3** is an exploded perspective view of an exemplary capacitive touch sensor panel formed from a top layer of glass upon which transparent column traces of ITO have been etched, and a bottom layer of glass upon which row traces of ITO have been etched.

FIG. **4** illustrates an exemplary capacitive touch sensor panel fabricated using a double-sided ITO (DITO) substrate having column and row ITO traces formed on either side of the substrate, and bonded between a cover and an LCD using transparent adhesive according to one embodiment of this invention.

FIG. **5** is an exploded perspective view of an exemplary DITO substrate (with its thickness greatly exaggerated for purposes of illustration only) with columns and rows formed on either side according to one embodiment of this invention.

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FIG. **6** illustrates an exemplary flex circuit according to one embodiment of this invention, including flex circuit portions for connecting to the row and column traces, respectively, on either side of a DITO substrate, and a flex circuit portion for connecting to a host processor.

FIG. **7** is an exploded perspective view of an exemplary DITO substrate (with its thickness greatly exaggerated for purposes of illustration only) with columns and rows formed on either side, and small isolated squares between the columns and rows to provide a uniform appearance.

FIG. **8** illustrates a stackup of an exemplary double-sided touch panel along with a cover and liquid crystal display (LCD) according to one embodiment of this invention.

FIG. **9** is a perspective view of an exemplary DITO substrate (with its thickness greatly exaggerated for purposes of illustration only) illustrating the widening of rows for shielding purposes and for providing a uniform appearance according to one embodiment of this invention.

FIG. **10a** illustrates an exemplary mobile telephone that can include the capacitive touch sensor panel and a flex circuit capable of connecting to both sides of the substrate according to one embodiment of this invention.

FIG. **10b** illustrates an exemplary digital audio player that can include the capacitive touch sensor panel and a flex circuit capable of connecting to both sides of the substrate according to one embodiment of this invention.

#### DETAILED DESCRIPTION

In the following description of preferred embodiments, reference is made to the accompanying drawings which form a part hereof, and in which it is shown by way of illustration specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the preferred embodiments of the present invention.

Multi-touch sensor panels and their associated sensor panel circuitry may be able to detect multiple touches (touch events or contact points) that occur at about the same time, and identify and track their locations. FIG. **1** illustrates exemplary computing system **100** operable with capacitive multi-touch sensor panel **124** according to embodiments of this invention. Multi-touch sensor panel **124** can be created using a substrate with column and row traces formed on either side of the substrate using a novel fabrication process. Flex circuits can be used to connect the column and row traces on either side of the sensor panel to its associated sensor panel circuitry. Traces made of copper or other highly conductive metals running along the edge of the substrate can be used to bring the row traces to the same edge of the substrate as the column traces so that the flex circuits can be bonded to the same edge of the substrate on directly opposing sides of the substrate, minimizing the area needed for connectivity and reducing the overall size of the sensor panel. A single flex circuit can be fabricated to connect to the rows and columns on directly opposing sides at the same edge of the substrate. Furthermore, the row traces can be widened to shield the column traces from a modulated Vcom layer.

Computing system **100** can include one or more panel processors **102** and peripherals **104**, and panel subsystem **106**. The one or more processors **102** can include, for example, an ARM968 processors or other processors with similar functionality and capabilities. However, in other embodiments, the panel processor functionality can be implemented instead by dedicated logic such as a state machine.

Peripherals **104** can include, but are not limited to, random access memory (RAM) or other types of memory or storage, watchdog timers and the like.

Panel subsystem **106** can include, but is not limited to, one or more analog channels **108**, channel scan logic **110** and driver logic **114**. Channel scan logic **110** can access RAM **112**, autonomously read data from the analog channels and provide control for the analog channels. This control can include multiplexing columns of multi-touch panel **124** to analog channels **108**. In addition, channel scan logic **110** can control the driver logic and stimulation signals being selectively applied to rows of multi-touch panel **124**. In some embodiments, panel subsystem **106**, panel processor **102** and peripherals **104** can be integrated into a single application specific integrated circuit (ASIC).

Driver logic **114** can provide multiple panel subsystem outputs **116** and can present a proprietary interface that drives high voltage driver, which is comprised of decoder **120** and subsequent level shifter and driver stage **118**, although level-shifting functions could be performed before decoder functions. Level shifter and driver **118** can provide level shifting from a low voltage level (e.g. CMOS levels) to a higher voltage level, providing a better signal-to-noise (S/N) ratio for noise reduction purposes. Decoder **120** can decode the drive interface signals to one out of N outputs, whereas N is the maximum number of rows in the panel. Decoder **120** can be used to reduce the number of drive lines needed between the high voltage driver and panel **124**. Each panel row input **122** can drive one or more rows in panel **124**. In some embodiments, driver **118** and decoder **120** can be integrated into a single ASIC. However, in other embodiments driver **118** and decoder **120** can be integrated into driver logic **114**, and in still other embodiments driver **118** and decoder **120** can be eliminated entirely.

Computing system **100** can also include host processor **128** for receiving outputs from panel processor **102** and performing actions based on the outputs that can include, but are not limited to, moving an object such as a cursor or pointer, scrolling or panning, adjusting control settings, opening a file or document, viewing a menu, making a selection, executing instructions, operating a peripheral device connected to the host device, answering a telephone call, placing a telephone call, terminating a telephone call, changing the volume or audio settings, storing information related to telephone communications such as addresses, frequently dialed numbers, received calls, missed calls, logging onto a computer or a computer network, permitting authorized individuals access to restricted areas of the computer or computer network, loading a user profile associated with a user's preferred arrangement of the computer desktop, permitting access to web content, launching a particular program, encrypting or decoding a message, and/or the like. Host processor **128** can also perform additional functions that may not be related to panel processing, and can be coupled to program storage **132** and display device **130** such as a liquid crystal display (LCD) for providing a UI to a user of the device.

As mentioned above, multi-touch panel **124** can in some embodiments include a capacitive sensing medium having a plurality of row traces or driving lines and a plurality of column traces or sensing lines (although other sensing media may also be used) separated by a dielectric. In some embodiments, the dielectric material can be transparent, such as glass, or can be formed from other materials such as Mylar. The row and column traces can be formed from a transparent conductive medium such as ITO or ATO, although other transparent or non-transparent materials such as copper can also be used. In some embodiments, the row and column

traces can be perpendicular to each other, although in other embodiments other non-orthogonal and non-Cartesian orientations are possible. For example, in a polar coordinate system, the sensing lines can be concentric circles and the driving lines can be radially extending lines (or vice versa). It should be understood, therefore, that the terms "row" and "column," "first dimension" and "second dimension," or "first axis" and "second axis" as may be used herein are intended to encompass not only orthogonal grids, but the intersecting traces of other geometric configurations having first and second dimensions (e.g. the concentric and radial lines of a polar-coordinate arrangement).

At the "intersections" of the traces, where the traces pass above and below each other (but do not make direct electrical contact with each other), the traces essentially form two electrodes (although more than two traces could intersect as well). Each intersection of row and column traces can represent a capacitive sensing node and can be viewed as picture element (pixel) **126**, which can be particularly useful when multi-touch panel **124** is viewed as capturing an "image" of touch. (In other words, after multi-touch subsystem **106** has determined whether a touch event has been detected at each touch sensor in the multi-touch panel, the pattern of touch sensors in the multi-touch panel at which a touch event occurred can be viewed as an "image" of touch (e.g. a pattern of fingers touching the panel).) The capacitance between row and column electrodes appears as a stray capacitance on all columns when the given row is held at DC and as a mutual capacitance  $C_{sig}$  when the given row is stimulated with an AC signal. The presence of a finger or other object near or on the multi-touch panel can be detected by measuring changes to  $C_{sig}$ . The columns of multi-touch panel **124** can drive one or more analog channels **108** (also referred to herein as event detection and demodulation circuits) in multi-touch subsystem **106**. In some embodiments, each column is coupled to one dedicated analog channel **108**. However, in other embodiments, the columns may be coupleable via an analog switch to a fewer number of analog channels **108**.

FIG. **2a** illustrates exemplary capacitive multi-touch panel **200**. FIG. **2a** indicates the presence of a stray capacitance  $C_{stray}$  at each pixel **202** located at the intersection of a row **204** and a column **206** trace (although  $C_{stray}$  for only one column is illustrated in FIG. **2** for purposes of simplifying the figure). Note that although FIG. **2a** illustrates rows **204** and columns **206** as being substantially perpendicular, they need not be so aligned, as described above. In the example of FIG. **2a**, AC stimulus  $V_{stim}$  **214** is being applied to one row, with all other rows connected to DC. The stimulus causes a charge to be injected into the column electrodes through mutual capacitance at the intersecting points. This charge is  $Q_{sig} = C_{sig} \times V_{stim}$ . Each of columns **206** may be selectively connectable to one or more analog channels (see analog channels **108** in FIG. **1**).

FIG. **2b** is a side view of exemplary pixel **202** in a steady-state (no-touch) condition. In FIG. **2b**, an electric field of electric field lines **208** of the mutual capacitance between column **206** and row **204** traces or electrodes separated by dielectric **210** is shown.

FIG. **2c** is a side view of exemplary pixel **202** in a dynamic (touch) condition. In FIG. **2c**, finger **212** has been placed near pixel **202**. Finger **212** is a low-impedance object at signal frequencies, and has an AC capacitance  $C_{finger}$  from the column trace **204** to the body. The body has a self-capacitance to ground  $C_{body}$  of about 200 pF, where  $C_{body}$  is much larger than  $C_{finger}$ . If finger **212** blocks some electric field lines **208** between the row and column electrodes (those fringing fields that exit the dielectric and pass through the air

above the row electrode), those electric field lines are shunted to ground through the capacitance path inherent in the finger and the body, and as a result, the steady state signal capacitance  $C_{sig}$  is reduced by  $\Delta C_{sig}$ . In other words, the combined body and finger capacitance act to reduce  $C_{sig}$  by an amount  $\Delta C_{sig}$  (which can also be referred to herein as  $C_{sig\_sense}$ ), and can act as a shunt or dynamic return path to ground, blocking some of the electric fields as resulting in a reduced net signal capacitance. The signal capacitance at the pixel becomes  $C_{sig} - \Delta C_{sig}$ , where  $C_{sig}$  represents the static (no touch) component and  $\Delta C_{sig}$  represents the dynamic (touch) component. Note that  $C_{sig} - \Delta C_{sig}$  may always be nonzero due to the inability of a finger, palm or other object to block all electric fields, especially those electric fields that remain entirely within the dielectric material. In addition, it should be understood that as a finger is pushed harder or more completely onto the multi-touch panel, the finger can tend to flatten, blocking more and more of the electric fields, and thus  $\Delta C_{sig}$  can be variable and representative of how completely the finger is pushing down on the panel (i.e. a range from "no-touch" to "full-touch").

Referring again to FIG. 2a, as mentioned above,  $V_{stim}$  signal 214 can be applied to a row in multi-touch panel 200 so that a change in signal capacitance can be detected when a finger, palm or other object is present.  $V_{stim}$  signal 214 can be generated as one or more pulse trains 216 at a particular frequency, with each pulse train including a number of pulses. Although pulse trains 216 are shown as square waves, other waveshapes such as sine waves can also be employed. A plurality of pulse trains 216 at different frequencies can be transmitted for noise reduction purposes to detect and avoid noisy frequencies.  $V_{stim}$  signal 214 essentially injects a charge into the row, and can be applied to one row of multi-touch panel 200 at a time while all other rows are held at a DC level. However, in other embodiments, the multi-touch panel can be divided into two or more sections, with  $V_{stim}$  signal 214 being simultaneously applied to one row in each section and all other rows in that region section held at a DC voltage.

Each analog channel coupled to a column measures the mutual capacitance formed between that column and the row. This mutual capacitance is comprised of the signal capacitance  $C_{sig}$  and any change  $C_{sig\_sense}$  in that signal capacitance due to the presence of a finger, palm or other body part or object. These column values provided by the analog channels may be provided in parallel while a single row is being stimulated, or may be provided in series. If all of the values representing the signal capacitances for the columns have been obtained, another row in multi-touch panel 200 can be stimulated with all others held at a DC voltage, and the column signal capacitance measurements can be repeated. Eventually, if  $V_{stim}$  has been applied to all rows, and the signal capacitance values for all columns in all rows have been captured (i.e. the entire multi-touch panel 200 has been "scanned"), a "snapshot" of all pixel values can be obtained for the entire multi-touch panel 200. This snapshot data can be initially saved in the multi-touch subsystem, and later transferred out for interpretation by other devices in the computing system such as the host processor. As multiple snapshots are obtained, saved and interpreted by the computing system, it is possible for multiple touches to be detected, tracked, and used to perform other functions.

As described above, because the rows may be either stimulated with an AC signal or held at a DC voltage level, and because the columns need to be connected to analog channels so that modulated output signals can be detected, demodulated and converted to output values, electrical connections

must be formed with the rows and columns on either side of the dielectric of the sensor panel.

FIG. 3 is an exploded perspective view of an exemplary capacitive touch sensor panel 300 formed from a top layer of glass 302 upon which transparent column traces of ITO 304 have been etched, and a bottom layer of glass 306 upon which row traces of ITO 308 have been etched. The top and bottom glass layers 302 and 306 are separated by a clear polymer spacer 310 that acts as a dielectric between the row and column traces. Because the rows and columns are perpendicular to each other, the most straightforward way to connect to these rows and columns is to bond flex circuit 312 at one edge of the sensor panel, and bond another flex circuit 314 on an adjacent edge of the sensor panel. However, because the connection areas for these flex circuits 312 and 314 are not on the same edge of sensor panel 300 and are not on directly opposing sides of dielectric 310, the sensor panel must be made larger to accommodate these two non-overlapping connection areas.

Capacitive touch sensor panels typically form the row and column traces on two pieces of glass as shown in FIG. 3 because it has not been practical to form column and row traces on either side of a single substrate. Conventional methods for forming ITO traces on one side of a substrate require that the substrate be placed on rollers during the fabrication process. However, if the substrate is then flipped over to form ITO traces on the second side, the rollers will damage any traces previously formed on the first side of the substrate. Furthermore, when etching is used to etch away part of the ITO to form traces on one side of the substrate, the entire substrate is conventionally placed in an etching bath, which will etch away any traces previously formed on the other side of the substrate.

FIG. 4 illustrates an exemplary capacitive touch sensor panel 400 fabricated using a double-sided ITO (DITO) substrate 402 having column and row ITO traces 404 and 406, respectively, formed on either side of the substrate, and bonded between cover 408 and LCD 410 using transparent adhesive 412 according to embodiments of this invention. Substrate 402 can be formed from glass, plastic, hybrid glass/plastic materials, and the like. Cover 408 can be formed from glass, acrylic, sapphire, and the like. To connect to column and row traces 404 and 406, respectively, two flex circuit portions 414 can be bonded to directly opposing sides at the same edge of DITO 402, although other bonding locations may also be employed.

FIG. 5 is an exploded perspective view of an exemplary DITO substrate 500 (with its thickness greatly exaggerated for purposes of illustration only) with columns 502 and rows 508 formed on either side according to embodiments of this invention. Some of column ITO traces 502 on the top side are routed to a necked-down connector area 504, where they are brought off the panel by a flex circuit portion 506 that can be conductively bonded to the top of DITO substrate 500. In some embodiments, row ITO traces 508 on the bottom side can be connected to thin metal traces 510 that run alongside the edges of the bottom side. Metal traces 510 can be routed to connector area 512, which can be directly opposing connector area 504, or at least on the same edge of DITO substrate 500 as connector area 504. Providing connector areas 504 and 512 at the same edge of DITO substrate 500 can allow the substrate and therefore the product to be smaller. Another flex circuit portion 514 can be used to bring row ITO traces 508 off the panel.

Column and row ITO traces 502 and 508 can be formed on both sides of DITO substrate 500 using several fabrication methods. In one embodiment, a substrate can be placed on the

rollers of the fabrication machinery and a layer of ITO can be sputtered onto a first side of DITO substrate **500** and etched (e.g. using photolithography techniques) to form column traces **502**. A protective coating of photoresist (e.g. two layers of photoresist) can then be applied over the column traces **502**, and DITO substrate **500** can be flipped over so that the rollers make contact only with the applied photoresist on the first side and not the formed column traces. Another layer of ITO can then be sputtered onto the now-exposed back side of DITO substrate **500** and etched to form row traces **508**.

If no metal traces **510** are required, the photoresist on the first side can be stripped off to complete the process. However, if metal traces **510** are required at the edges to connect to row traces **508** and bring them to a particular edge of the substrate, a protective coating of photoresist (e.g. two layers of photoresist) can be applied over row traces **508**, leaving the edges exposed. A metal layer can then be sputtered over the photoresist and exposed edges, and the metal layer can then be etched to form metal traces **510** at the edges. Finally, all remaining layers of photoresist can be stripped off.

Minor variations to the process described above can also be made. For example, the second side of the DITO substrate patterning may be formed by first patterning a photoresist using very simple geometry to cover only the interior region of the second side of the DITO substrate while leaving the edge regions exposed. For this variation, metal is sputtered first and then the photoresist with simple geometry is then stripped off to leave metal in the edge regions only. Then the ITO is sputtered over the entire second side of the DITO substrate. A second photoresist is applied and patterned to form the mask for the electrode patterns. A series of etching steps is then used to form the electrode pattern in the topmost ITO layer and metal layer underneath. The first etching steps etches the ITO only, and the second etch steps etches the metal layer only which produces the desired electrode geometry.

FIG. 6 illustrates an exemplary flex circuit **600** according to embodiments of this invention, including flex circuit portions **606** and **614** for connecting to the row and column traces, respectively, on either side of a DITO substrate, and flex circuit portion **608** for connecting to a host processor. Flex circuit **600** includes a circuit area **602** upon which the multi-touch subsystem, multi-touch panel processor, the high voltage driver and decoder circuitry (see FIG. 1), an EEPROM and some essential small components such as bypass capacitors can be mounted and connected to save space. Circuit area **602** may be shielded by an EMI can (not shown) which encloses circuit area **602** using top and bottom shield portions. The bottom can may be adhered to a structure of the device to secure the circuit area. From this circuit area **602**, flex circuit **600** may connect to the top of the DITO substrate via flex circuit portion **606**, to the bottom of the DITO substrate via flex circuit portion **614**, and to a host processor via flex circuit portion **608**.

FIG. 7 is an exploded perspective view of an exemplary DITO substrate **700** (with its thickness greatly exaggerated for purposes of illustration only) with columns **702** and rows **708** formed on either side. As shown in FIG. 7, column traces **702** can be about 1 mm wide, with a spacing of about 4 mm between the traces, and row traces **708** can be about 2 mm wide, with a spacing of about 3 mm between the rows. To create a more uniform appearance, small isolated squares of ITO **704** can be formed between the column and row traces **702** and **708** on either side of DITO substrate **700**, with narrow spacing (e.g. about 30 microns) between the isolated squares of ITO, so that either side of the DITO substrate provides a uniform appearance similar to a solid sheet of ITO.

FIG. 8 illustrates a stackup of an exemplary double-sided touch panel **800** along with cover **802** and liquid crystal display (LCD) **804** according to embodiments of this invention. From top to bottom, LCD **804** can include polarizer **806**, top glass layer **808**, liquid crystal layer **810**, bottom glass layer **812**, polarizer **814**, and backlight **816**.

From top to bottom, liquid crystal layer **810** can include RGB color filter layer **818**, planarization layer **820**, a conductive unpatterned layer of ITO referred to as Vcom layer **822**, polyamide layer **824**, liquid crystal layer **826**, and polyamide layer **828**. Beneath polyamide layer **828** is a layer of ITO rectangles and TFTs (collectively referred to herein as TFT layer **830**), with one ITO rectangle and TFT for each sub-pixel (where three sub-pixels comprise a pixel).

Color filter layer **818** provides the three RGB colors that make up each pixel when illuminated by light, wherein the ratio of colors determines the color of that pixel. Planarization layer **820** can be formed from clear plastic to smooth out the surface of color filter layer **818**. Vcom stands for "Voltage common" because Vcom layer **822** provides a common voltage for the ITO subpixels of TFT layer **830**. Vcom layer **822** may be maintained at a constant voltage (LCDs using a constant Vcom voltage may be referred to as DC or constant Vcom LCDs) or modulated with an AC signal. Polyamide layers **824** and **828** serve to pre-align the orientation of liquid crystals in liquid crystal layer **826**. To create the color for one pixel, the ITO squares for each subpixel in TFT layer **830** can have voltages applied to them with respect to Vcom layer **822**, which causes the liquid crystals to align and allow light from backlight **816** to pass through liquid crystal layer **826** and through the RGB color filters in color filter layer **818**.

As mentioned above, although Vcom layer **822** can be held constant, in some embodiments the Vcom layer can be driven by a modulated signal (e.g. a squarewave from about 1 to 4 volts). However, when Vcom layer **822** is driven by a modulated signal, the modulated signal may be capacitively coupled (see reference character **834**) through the sparse conductors of rows **836** on the bottom of double-sided touch panel **800** and onto columns **838**, causing noise on the columns. Note that rows **836** are referred to as "sparse," even though it includes many closely spaced ITO squares, because the squares are isolated and therefore of negligible effect from a shielding standpoint. Note also that although modulated Vcom layer **822** is also capacitively coupled onto rows **836**, because the rows are being driven by driver circuitry with low impedance outputs, any capacitive coupling is shunted to the driver outputs, and has negligible effect. However, columns **838** are designed to sense small changes in the AC capacitance of the touch panel, so the capacitive coupling from modulated Vcom layer **822** can easily be seen as noise at the analog channels receiving the columns.

FIG. 9 is a perspective view of an exemplary DITO substrate **900** (with its thickness greatly exaggerated for purposes of illustration only) illustrating the widening of rows **936** for shielding purposes and for providing a uniform appearance according to embodiments of this invention. To prevent the capacitive coupling of a modulated Vcom layer onto columns **938**, rows **936** may be widened as shown in FIG. 9. The number of rows **936** does not change, but they are now much wider (e.g. about 4.97 mm), leaving only about 30 microns of space between them. Because these wider rows **936** are not isolated but are instead either held at a DC voltage or stimulated with a stimulation voltage, these wider rows **936** act as a shield, preventing a modulated Vcom layer from capacitively coupling onto columns **938**. In addition, because of the narrow spacing between them, rows **936** provide a uniform appearance. Thus, shielding, modulation and a uniform

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appearance can be obtained from a single layer of ITO. Note that although FIG. 9 illustrates rows and columns formed on opposite sides of a single substrate, wide rows can also be employed on the otherwise conventional touch sensor panel shown in FIG. 3. An alternative to these wide rows is to add another layer of ITO as a shield between the LCD and DITO, but this would represent extra cost, extra thickness, light loss, and unwanted color shift.

As mentioned above, top side of an exemplary DITO substrate according to embodiments of the invention may include isolated ITO squares between rows, and a bottom side may include wide rows. Outer row traces can be routed to a first flex connector area on the top side via traces. Rows on the bottom side can be routed to second flex connector areas via metal traces running along the long edges of the bottom side. Note that the second flex connector areas can be located on the same edge of the DITO substrate as the first flex connector, but the conductors themselves are located in non-overlapping areas to make bonding of flex circuits easier.

FIG. 10a illustrates an exemplary mobile telephone 1136 that can include capacitive touch sensor panel 1124 and flex circuit 1134 capable of connecting to both sides of the substrate according to embodiments of this invention. Sensor panel 1124 can be fabricated using a substrate having column and row ITO traces formed on either side of the substrate, and metal traces form along the edges of one side of the substrate to allow flex circuit connection areas to be located on opposing sides of the same edge of the substrate. Furthermore, sensor panel 1134 can be fabricated with wide rows to provide modulated Vcom layer shielding as well as a uniform appearance. FIG. 10b illustrates an exemplary digital audio/video player 1138 that can include capacitive touch sensor panel 1124 and flex circuit 1134 capable of connecting to both sides of the substrate according to embodiments of this invention. Sensor panel 1124 can be fabricated using a substrate having column and row ITO traces formed on either side of the substrate, and metal traces form along the edges of one side of the substrate to allow flex circuit connection areas to be located on opposing sides of the same edge of the substrate. Furthermore, sensor panel 1134 can be fabricated with wide rows to provide modulated Vcom layer shielding as well as a uniform appearance. The mobile telephone and digital audio/video player of FIGS. 10a and 10b can advantageously benefit from sensor panel 1124 because a single, thinner, smaller-sized sensor panel can be used, and only a single layer of ITO is needed to provide shielding and a uniform appearance. The overall effect is reduced product size and manufacturing costs.

Although the present invention has been fully described in connection with embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art. Such changes and modifications are to be understood as being included within the scope of the present invention as defined by the appended claims.

What is claimed is:

1. A capacitive touch sensor panel, comprising:

a first set of traces of conductive material arranged along a first dimension of a two-dimensional coordinate system, the first set of traces having one or more widths including a maximum width; and

a second set of traces of the conductive material spatially separated from the first set of traces by a dielectric and arranged along a second dimension of the two-dimensional coordinate system, the second set of traces having one or more widths including a minimum width;

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wherein the minimum width of the second set of traces is substantially greater than the maximum width of the first set of traces at least at an intersection of the first and second sets of traces to provide shielding from display interference for the first set of traces; and

wherein sensors are formed at locations at which the first set of traces intersects with the second set of traces while separated by the dielectric.

2. The capacitive touch sensor panel of claim 1, further comprising a display adjacent to the touch sensor panel, the display capable of emitting noise, and the second set of traces configured for shielding the first set of traces from the noise.

3. The capacitive touch sensor panel of claim 1, wherein the second set of traces are widened to substantially electrically isolate the first set of traces from noise from a display.

4. The capacitive touch sensor panel of claim 1, further comprising a computing system that incorporates the touch sensor panel.

5. The capacitive touch sensor panel of claim 4, further comprising a handheld computing device that incorporates the computing system.

6. A digital audio player having a capacitive touch sensor panel, the touch sensor panel comprising:

a first set of traces of conductive material arranged along a first dimension of a two-dimensional coordinate system, the first set of traces having one or more widths including a maximum width; and

a second set of traces of the conductive material spatially separated from the first set of traces by a dielectric and arranged along a second dimension of the two-dimensional coordinate system, the second set of traces having one or more widths including a minimum width;

wherein the minimum width of the second set of traces is substantially greater than the maximum width of the first set of traces at least at an intersection of the first and second sets of traces to provide shielding from display interference for the first set of traces; and

wherein sensors are formed at locations at which the first set of traces intersects with the second set of traces while separated by the dielectric.

7. The digital audio player of claim 6, further comprising a display adjacent to the touch sensor panel, the display capable of emitting noise, and the second set of traces configured for shielding the first set of traces from the noise.

8. The digital audio player of claim 6, wherein the second set of traces are widened to substantially electrically isolate the first set of traces from noise from a display.

9. A capacitive touch sensor panel, comprising:

sense traces having one or more widths including a maximum width; and

drive traces spatially separated from the sense traces by a dielectric, the drive traces having one or more widths including a minimum width, the minimum width of the drive traces being substantially greater than the maximum width of the sense traces at least at an intersection of the sense and drive traces to provide shielding from display interference for the sense traces;

wherein sensors are formed at locations at which the sense traces intersect with the drive traces while separated by the dielectric.

10. The capacitive touch sensor panel of claim 9, further comprising a display adjacent to the touch sensor panel, the display capable of emitting noise, and the drive traces configured for shielding the sense traces from the noise.

11. The capacitive touch sensor panel of claim 9, wherein the drive traces are widened to substantially electrically isolate the sense traces from noise from a display.



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12. The capacitive touch sensor panel of claim 9, further comprising a computing system that incorporates the touch sensor panel.

13. The capacitive touch sensor panel of claim 12, further comprising a handheld computing device that incorporates the computing system.

14. A method for shielding a capacitive touch sensor panel from capacitive coupling of modulated signals, comprising:

forming a first set of sense traces having one or more widths including a maximum width;

orienting the sense traces along a first dimension of a two-dimensional coordinate system;

forming a second set of drive traces spatially separated from the first set of sense traces by a dielectric, the second set of drive traces having one or more widths including a minimum width, the minimum width of the drive traces being substantially greater than the maximum width of the sense traces at least at an intersection of the first and second sets of traces to provide shielding from display interference for the sense traces; and

orienting the drive traces along a second dimension of the two-dimensional coordinate system to form sensors at locations at which the sense traces intersect with the drive traces while separated by the dielectric.

15. The method of claim 14, further comprising affixing a display adjacent to a side of the touch sensor panel closest to the drive traces, the display capable of emitting noise.

16. The method of claim 14, further comprising widening the drive traces to substantially electrically isolate the sense traces from noise from a display.

17. A method for shielding a capacitive touch sensor panel from a source of capacitive coupling, comprising:

forming a first set of traces further from the source of capacitive coupling than a second set of traces, the first set of traces configured for sensing changes in mutual capacitance, the first set of traces having one or more widths including a maximum width;

orienting the first set of traces along a first dimension of a two-dimensional coordinate system;

forming the second set of traces closer to the source of capacitive coupling than the first set of traces and spatially separated from the first set of traces by a dielectric, the second set of traces having one or more widths including a minimum width, the minimum width of the second set of traces being substantially greater than the maximum width of the first set of traces at least at an intersection of the first and second sets of traces to provide shielding from display interference for the first set of traces, the second set of traces configured for being driven by low impedance driver outputs; and

orienting the second set of traces along a second dimension of the two-dimensional coordinate system to form sensors at locations at which the first set of traces intersects with the second set of traces while separated by the dielectric.

18. The method of claim 17, further comprising widening the drive traces to substantially electrically isolate the sense traces from noise from a display.

19. A capacitive touch sensor panel, comprising:

sense traces formed on a first layer and arranged along a first dimension of a two-dimensional coordinate system; and

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drive traces formed on a second layer spatially separated from the first layer by a dielectric, the drive traces arranged along a second dimension of the two-dimensional coordinate system;

wherein the drive traces are widened as compared to the sense traces to substantially cover the second layer except for a gap between adjacent drive traces so as to substantially electrically isolate the sense traces from interference from a display;

wherein sensors are formed at locations at which the sense traces intersect with the drive traces while separated by the dielectric; and

wherein each of the drive traces is of a substantially constant width.

20. The capacitive touch sensor panel of claim 19, further comprising a display adjacent to the touch sensor panel, the display capable of emitting noise, and the drive traces configured for shielding the sense traces from the noise.

21. The capacitive touch sensor panel of claim 19, further comprising a computing system that incorporates the touch sensor panel.

22. The capacitive touch sensor panel of claim 21, further comprising a handheld computing device that incorporates the computing system.

23. A method for shielding a capacitive touch sensor panel from coupling of modulated signals, comprising:

forming a first set of sense traces on a first layer;

orienting the sense traces along a first dimension of a two-dimensional coordinate system;

forming a second set of widened drive traces on a second layer spatially separated from the first layer, the drive traces widened as compared to the sense traces to substantially cover the second layer except for a gap between adjacent drive traces so as to substantially electrically isolate the first set of sense traces from interference from a display; and

orienting the drive traces along a second dimension of the two-dimensional coordinate system to form sensors at locations at which the sense traces intersect with the drive traces;

wherein each of the drive traces is of a substantially constant width.

24. A touch sensitive computing system, comprising:

a touch processor;

a display;

a touch sensor panel adjacent to the display and coupled to the touch processor, the touch sensor panel including sense traces formed on a first layer, and

drive traces formed on a second layer spatially separated from the first layer, the drive traces widened as compared to the sense traces to substantially cover the second layer except for a gap between adjacent drive traces so as to substantially electrically isolate the sense traces from interference from a display, wherein sensors are formed at locations at which the sense traces intersect with the drive traces; and wherein each of the drive traces is of a substantially constant width.

25. The touch sensitive computing system of claim 24, wherein the computing system is incorporated into a handheld computing device.

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